

# Quantitative Image Analysis Techniques with High-Speed Schlieren Photography

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Optical flow visualization techniques such as schlieren and shadowgraph photography are essential to understanding fluid flow when interpreting acquired wind tunnel test data. Output of the standard implementations of these visualization techniques in test facilities are often limited only to qualitative interpretation of the resulting images. Although various quantitative optical techniques have been developed, these techniques often require special equipment or are focused on obtaining very precise and accurate data about the visualized flow. These systems are not practical in small, production wind tunnel test facilities. However, high-speed photography capability has become a common upgrade to many test facilities in order to better capture images of unsteady flow phenomena such as oscillating shocks and flow separation.

This paper describes novel techniques utilized by the authors to analyze captured high-speed schlieren and shadowgraph imagery from wind tunnel testing for quantification of observed unsteady flow frequency content. Such techniques have applications in parametric geometry studies and in small facilities where more specialized equipment may not be available.

## Nomenclature

ARF	=	Aerodynamic Research Facility
EV33	=	MSFC Aerosciences Branch
LAS	=	Launch Abort System
MSFC	=	NASA Marshall Space Flight Center
SLS	=	Space Launch System
TWT	=	Trisonic Wind Tunnel
USA2	=	Upper Stage Adapter 2

## I. Introduction

Large scale wind tunnel testing is the method of choice for the characterization of launch vehicle unsteady aerodynamics. Ideally a model is fitted with miniature pressure transducers and frequency data is collected. Unfortunately large scale testing is often expensive and time consuming. To make informed engineering decisions in a timely manner smaller scale tests are needed. These smaller test facilities, models, time-frames, and budgets do not allow for the use of pressure transducers and instead rely on optical techniques.

The Aerosciences Branch at the Marshall Space Flight Center (MSFC) has conducted a test at the MSFC Aerodynamic Research Facility (ARF) Trisonic Wind Tunnel (TWT) in order to determine the effects of geometry changes of the Universal Stage Adapter 2 (USA2). Using a 0.6% scale truncated model of the NASA Space Launch

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System (SLS) Block 1B vehicle. There were seven geometries of the USA tested over a Mach number range of 0.8 through 1.3 and at angles of attack between  $\pm 8$  deg.